URBANIZATION AND THE EFFICIENCY OF CARBON DIOXIDE AND GRAVID TRAPS FOR SAMPLING *CULEX QUINQUEFASCIATUS*

RICHARD P. MEYER

Kern Mosquito and Vector Control District, P.O. Box 9428, Bakersfield, CA 93389

ABSTRACT. The efficiency of gravid and CO_2 traps for sampling female *Culex quinquefasciatus* was evaluated along 2 parallel 6.4 km long urban (high housing density) to rural (low housing density) transects in east Bakersfield, Kern County, CA. There were no significant differences in the number of female *Cx. quinquefasciatus* collected by gravid traps within urban and rural zones. The number of females collected per trap night ranged from 6.8 to 15.5. The number of females collected by CO_2 traps increased significantly from 1.4 to 3.1 per trap night in urban to 31.8 to 111.2 per trap night in rural zones and was inversely correlated with housing density. These results indicate that female *Cx. quinquefasciatus* were effectively sampled by gravid traps in urban subdivisions and by CO_2 traps in rural mixed agricultural areas.

INTRODUCTION

Throughout the coastal and interior valleys of California, *Culex quinquefasciatus* Say is the predominant urban pest mosquito associated with a variety of foul water breeding sources (Bohart and Washino 1978). Recent outbreaks of St. Louis encephalitis (SLE) in the Los Angeles basin (Emmons et al. 1985, Webb et al. 1987) and southern San Joaquin Valley (Emmons et al. 1990, Reisen et al. 1990b) implicated this species as a possible secondary vector. Adult populations of *Cx. quinquefasciatus* in California are sampled routinely by New Jersey light traps (Mulhern 1953), CO_2 traps [CDC miniature light traps (Sudia and Chamberlain 1962) baited with dry ice and operated without light] and gravid traps (Reiter 1983). The recent proliferation of security lighting in urban areas has greatly reduced the effectiveness of the New Jersey light trap for determining population abundances. Ecological studies in the Los Angeles basin proceeding the SLE outbreak in 1984 demonstrated that the effectiveness of CO_2 traps for sampling host-seeking females varied among urban neighborhoods (Reisen et al. 1990). Gravid traps operated concurrently at the same sites as the CO_2 traps collected significantly higher numbers of predominately gravid females. Considering the status of *Cx. quinquefasciatus* as a potential secondary vector of SLE in California, an improved sampling regimen for this species in urban environs would complement existing surveillance programs currently directed toward monitoring *Culex tarsalis* Coq., the primary vector of SLE in western North America (Reeves 1990).

Trap evaluation studies compared the operational efficiency of the CO_2 and gravid trap for sampling *Cx. quinquefasciatus* in urban and rural habitats with different housing densities.

MATERIALS AND METHODS

Study area: Trap evaluations were conducted in east Bakersfield, Kern County, CA, along 2 north to south parallel transects (T1 = Sterling Road and T2 = Fairfax Road) separated east to west by 0.8 km. Along each transect, traps were deployed at intervals of 1.6 km (6.4 km total length) to accommodate sampling in 5 zones with different housing densities (Fig. 1, Table 1). Zones 1 and 2 represented urban subdivisions with housing densities in the range of 800–1,558 dwellings/km^2. Zone 3 with 70–150 dwellings/km^2 was an area (1–1.5 km wide) of transition from gradually thinning subdivisions to dispersed rural housing in mixed agricultural areas. Housing densities in rural zones 4 and 5 ranged from 10 to 40 dwellings/km^2.

Trap placement and operation: A complement of one CO_2 and gravid trap was placed at a private residence within each zone and transect. Carbon dioxide traps were hung from standards 1.3 m above ground level, and gravid traps were placed on the ground in protected areas separated from CO_2 traps by a minimum of 5 meters. Each CO_2 trap was supplied with ca. 2 kg of dry ice. The hay infusion oviposition attractant/media (Reiter 1983) (3 liters) used in the reservoir of each gravid trap was replaced each night of trap operation.

Traps were operated from sunset to sunrise on 10 nights between mid-August and mid-September, 1990. Each CO_2 and gravid trap collection was scored to the number of female *Cx. quinquefasciatus* collected. The number of gravid females collected by gravid traps was recorded to obtain an overall percentage of gravid individuals captured by that method.

Data analyses: Collection data were transformed to log (Y + 1) and tested by 2-way ANOVA with transects and zones as main effects. The mean number collected in each zone

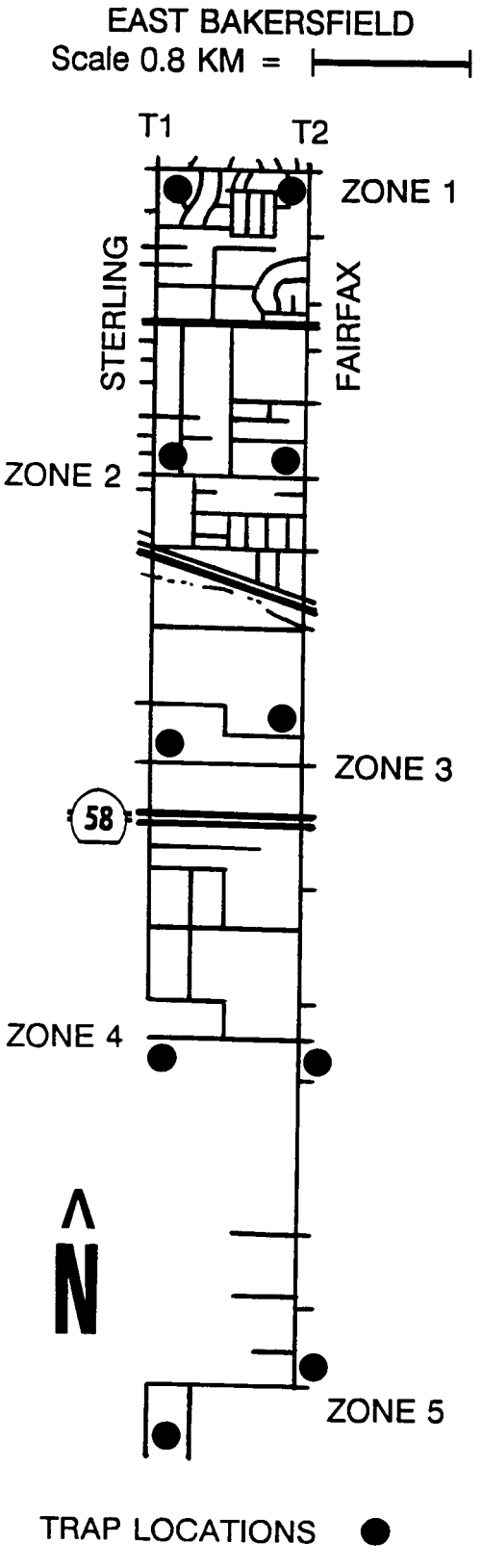

Fig. 1. Study area in east Bakersfield, Kern County, CA.

Table 1. Back-transformed means (Mw) of *Culex quinquefasciatus* females collected per trap night ($n = 10$) by gravid and CO_2 traps in each transect (T1 and T2) and zone.

	Mw of females collected per trap night			
	Gravid trap		CO_2 trap	
Zone	T1	T2	T1	T2
1	6.8a[1]	8.8a	1.5a	2.1a
2	10.5a	14.4a	1.4a	3.1a
3	12.5a	8.8a	11.2b	2.7a
4	8.9a	6.8a	111.2c	31.8d
5	15.5a	9.2a	100.5c	35.6d

[1] Zone means within trap type followed by the same letter are not significantly different in a Duncan's test ($P > 0.05$).

by either CO_2 trap or gravid trap was compared by a Duncan's multiple range test (a = 0.05). The relationship between the log (LN) of housing density and CO_2 trap catch size among zones ($n = 10$) was tested by regression analyses (Sokal and Rohlf 1981).

RESULTS

Prevailing weather conditions remained relatively constant from late summer to early fall and did not greatly influence trap operation. Diel temperature fluctuations measured at Meadows Field Airport (NOAA) 10 km N of Bakersfield were in the range of ca. 16 to 32°C. Maximum wind velocities from the NNW seldom exceeded 10 km/h between sunset and sunrise.

Inter- and intrazone differences in the back-transformed mean number (Mw) of female *Cx. quinquefasciatus* collected per trap night by CO_2 and gravid traps are summarized in Table 1. There were no significant ($P > 0.05$) differences in the number of females (ca. 92% gravid) collected by gravid traps operated in each zone (df = 4, 90) and transect (df = 1, 90). The number of females collected among all zone sites ranged between 6.8 and 15.5/trap night. By comparison, there was a significant difference in the number of host-seeking females collected by CO_2 traps between and within zones. Carbon dioxide trap counts were lowest (1.4–3.1/trap night) in urban zones 1 and 2, intermediate (2.7–11.8/trap night) in transition zone 3 and highest (31.8–111.2/trap night) in rural zones 4 and 5. Within zones 4 and 5, CO_2 trap counts in T1 were

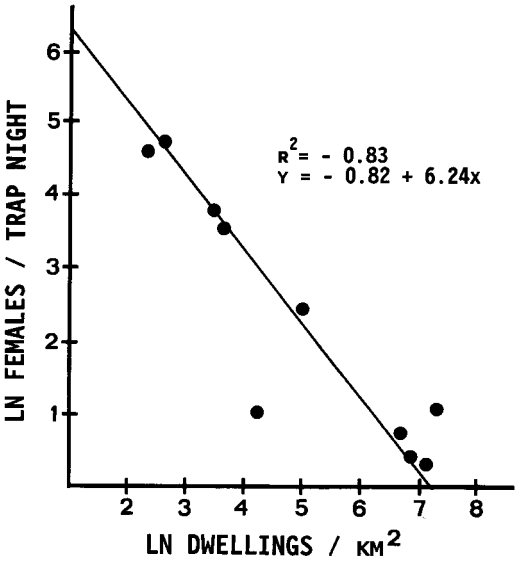

Fig. 2. Relationship between the mean number (LN) of female *Culex quinquefasciatus* collected per trap night by CO_2 traps and housing density (LN) within each zone ($n = 10$, $P < 0.01$, df = 8).

significantly higher ($P < 0.05$) than in T2. The decrease in the overall mean number of females collected by CO_2 traps from rural to urban zones was inversely correlated ($r = -0.91$, $P < 0.01$, df = 8) with housing density (Fig. 2).

The ratio of the number of females sampled by gravid trap to the number sampled by CO_2 trap was compared by zone (Table 2). There was a distinct reversal in the effectiveness of gravid versus CO_2 trap from urban to rural zones. Gravid traps collected more females within urban zones 1 and 2 than did CO_2 traps, but much less by comparison with CO_2 traps operated within rural zones 4 and 5. The ratio of gravid to CO_2 trapped females within transition zone 3 (T1) approached equality at 1.11:1.

DISCUSSION

This study was conducted in late summer when *Cx. quinquefasciatus* abundance reaches maximal levels in the southern San Joaquin Valley. Population increases are temporally coincidental with the period of the greatest potential for SLE transmission (Reeves 1990). The regional increase in abundance is related to the cumulative effects of hot summer temperatures and the progressive colonization of agricultural tailwater, dairy lagoons and urban drainage sumps.

Simultaneous operation of CO_2 and gravid traps in urban zones demonstrated that housing density significantly reduced the efficiency of the CO_2 trap for sampling host-seeking female *Cx. quinquefasciatus*. Few females were collected by traps operated in urban zones where housing densities were in excess of 800 dwellings/km^2. By comparison, housing density had no apparent influence on gravid trap efficiency as indicated by the relatively uniform number of females collected per trap night in all zones. Although gravid traps did not reveal any significant differences in zonal abundances, *Cx. quinquefasciatus* populations were probably more abundant in rural mixed agricultural habitats where breeding was more extensive than in nearby urban subdivisions. Thus, gravid traps may have proportionately underestimated female abundance in rural zones 4 and 5 where collection sizes were comparable to those in urban zones. Carbon dioxide traps similarly underestimated abundance in urban zones 1 and 2 (i.e., CO_2 trap collections < gravid trap collections). This apparent discontinuity in trap efficiency suggests a sampling confoundment introduced by 2 key environmental factors that affect ovipositional and host-seeking behavior: 1) access to and number of suitable breeding sources, and 2) distribution patterns of avian hosts in urban versus rural zones.

Previous studies of *Cx. quinquefasciatus* dispersal and breeding habits in the Los Angeles basin revealed that within urban subdivisions host-seeking females are evenly dispersed while gravid individuals tend to become aggregated (Reisen et al. 1990a). Neighborhood surveys of individual premises further revealed that diurnal resting shelters such as landscape vegetation and vertebrate hosts, primarily resident birds and domestic pets, were more uniformly distributed in comparison to typical rural environs. However, suitable breeding sources were uncommon and extremely localized at 10% of the premises surveyed. The relative uniformity in the distribution of competing avian hosts coupled with aggregated oviposition sites apparently reduced attraction to CO_2 traps, but increased attraction to gravid traps. Overall, this pattern of trap attractancy/effectiveness was in agreement with the data obtained from CO_2 and gravid traps operated concurrently within urban zones 1 and 2 and at one site (T2) in zone 3.

The opposite pattern of trapping efficiency was demonstrated in rural zones 4 and 5 where CO_2 traps collected substantially more females than gravid traps. It was presumed that within mixed agricultural zones 4 and 5 vertebrate hosts were localized at farm residences and interspersed areas of vegetative cover, while colonizable breeding sources were numerous and widespread. These environmental factors would

Table 2. Housing density and ratio of the number of female *Culex quinquefasciatus* collected by gravid trap to the number of females collected by CO_2 trap in each transect and zone.

Zone	Transect 1		Transect 2	
	Housing[1] density	Ratio[2] gravid:CO_2 trap	Housing density	Ratio gravid:CO_2 trap
1	800	4.6:1	800	4.2:1
2	1,250	7.4:1	1,588	4.7:1
3	150	1.1:1	70	3.3:1
4	14	0.1:1	40	0.2:1
5	10	0.2:1	30	0.3:1

[1] Estimated number of dwellings/km^2.
[2] Ratio of the number of females collected by gravid trap to the number of females collected by CO_2 trap.

tend to increase CO_2 trap attractancy, but proportionately decrease the attractiveness of gravid traps. Gravid traps placed near rural dairy lagoons in Chino, CA (Reisen and Pfuntner 1987), and in rural mixed agricultural areas near Bakersfield, CA (Reisen and Meyer 1990), collected few *Cx. quinquefasciatus*. By comparison, CO_2 traps effectively sampled host-seeking females at the dairy lagoons near Chino and at rural mixed agricultural sites in the present study.

Urban housing densities and presumed associated environmental conditions significantly reduced the efficiency of the CO_2 trap for sampling *Cx. quinquefasciatus*. The slight reduction in gravid trap efficiency in rural habitats may have been the result of competition from existing oviposition sites that are more extensive in mixed agricultural habitats. These results demonstrate that *Cx. quinquefasciatus* surveillance programs in California are better served by selective trapping strategies using gravid traps in urban habitats and CO_2 traps in rural habitats. Furthermore, live females collected by either method can be pooled and tested for the presence of arboviruses or examined for parity status as a variable used in determining vectorial capacity.

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